

# Advances in the Sub-nanometer Imaging and Spectroscopic Characterization of Materials Using Electron-optical Beamlines: An Overview

**Nestor J. Zaluzec**

Electron Microscopy Center, Argonne National Laboratory, Argonne, IL 60439

Electron-optical beamlines have undergone a revolutionary transformation in their capabilities in less than a decade. Part of this is the result of the evolution of our basic instrumentation, together with advances in detector systems, the remainder is due to our ability to design and execute computationally mediated experiments. The combination of these factors has given us modern electron-optical systems that allow unprecedented capabilities for probing the nature of how materials are characterized and at scales, which in some cases, surpass the 0.1-nm level.

On the imaging and diffraction front, the combination of coherent sub nanometer probes, image and probe correctors, together with tomographic and holographic reconstruction permits detailed observation and analysis of a wide range of problems ranging from medium range order in pseudo-amorphous solids, the nature of interfaces and defects in crystalline solids, imaging of magnetic and electrostatic fields in engineered materials, and probing the organic/inorganic interface. In biological systems, cryo-microscopy integrated with tomographic reconstruction now routinely provides the ability for researchers to study macromolecular assemblies and their components, from which 3D structures can be determined. Spectroscopically, a new generation of technologies allows the direct observation and measurement of elemental species using both x-ray and electron spectroscopy at the atomic level, while the ability of combining spectroscopy with orientation and/or momentum dependent elastic and inelastic scattering allow us to extract new and complementary information to routine “atomic resolution imaging.” Exemplar studies of the former will be used to illustrate how such capabilities are being used today.

*This work is supported by the US DOE Office of Science, Contract DE-AC02-06CH11357 in the ANL Electron Microscopy Center*